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TITLE OF THE INVENTION
INK-JET PRINTING APPARATUS AND METHOD, AND COMPUTER
READABLE MEMORY

5 FIELD OF THE INVENTION

The present invention relates to an ink-jet printing apparatus and method for printing a desired visible image by forming ink dots on a print medium by discharged ink droplets, and a computer readable memory.

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BACKGROUND OF THE INVENTION

Conventionally, as information processing apparatuses such as a copying machine, wordprocessor, computer, and the like, and communication apparatuses have prevailed and advanced, an apparatus for printing a digital image using an ink-jet print head has increasingly become prevalent as one of image forming (printing) apparatuses for those apparatuses. Also, since the aforementioned information processing apparatuses and communication apparatuses adopt high-quality, color graphic information, a printing apparatus is required to output a high-quality, color image.

Such printing apparatus uses a print head which comprises a print element array prepared by integrating and lining up a plurality of print elements, and on which a plurality of ink ejection ports and ink

channels are integrated at high density, so as to
miniaturize pixels. Furthermore, to obtain color
outputs, the printing apparatus normally comprises a
plurality of print heads corresponding to, e.g., cyan,
5 magenta, yellow, and black inks.

However, high-density integration of the ink
ejection ports and ink channels is limited and, hence,
miniaturization of pixels has a given limit. In such
case, since dots that form each pixel become relatively
10 large, they give rise to graininess in a low-density
image highlight portion or the like, and disturb
improvement of the image quality of an image.

By contrast, a so-called multi-drop scheme is
known. In this scheme, in place of increasing the
15 integration density of ink ejection ports and ink
channels (i.e., in place of reducing one pixel size),
the dot size of ink to be discharged is reduced and one
pixel is formed by ink droplets corresponding in number
to a print density. With the multi-drop scheme, since
20 the ink dot size printed on a print sheet can become
relatively small, graininess in a low-density portion
such as a highlight portion or the like can be
eliminated.

However, miniaturization of the ink droplet size
25 is limited in consideration of ejection stability upon
discharging small ink droplets, and bottlenecks the
improvement of image quality accordingly. In this

scheme, since the number of ink droplets to be discharged per pixel increases, the print speed lowers, and conflict between high image quality and high print speed occurs.

5 As another scheme for improving image quality without increasing the integration density of ink ejection ports, a multi-density printing scheme using multi-density (dark and light) inks of the same hue having different ink densities is known. In this
10 scheme, a highlight portion is printed using low-density light ink to reduce graininess of ink dots, and a high-density portion is printed using dark ink. Since this scheme need not increase the number of ink droplets to be discharged upon forming a high-density
15 portion unlike in the multi-drop scheme, an increase in print ink droplet amount and a decrease in print speed can be suppressed.

 Furthermore, in this multi-density printing scheme, inks used to express an output image density
20 corresponding to an input image density are determined using a multi-density ink distribution table (ink distribution table) shown in, e.g., Fig. 13. Fig. 13 shows an example of the contents of the multi-density ink distribution table using four types of
25 multi-density inks. (Optical densities of A-D inks are 1:2:4:8, A and B inks are light inks and C and D inks are dark inks.) Fig. 14 is a flow chart showing the

flow of an image process using the ink distribution table shown in Fig. 13.

The multi-density printing scheme rasterizes an input image in correspondence with individual inks using the multi-density ink distribution table based on the input image density. That is, in Fig. 14 an image is input (step S11), and undergoes a multi-valued process (step S12). Multi-density inks to be used are determined for the processed image using the multi-density ink distribution table (step S13).

After the multi-density inks used are determined, data is binarized by a binarization circuit (step S14) to generate drive signals for print element arrays a to d corresponding to inks A, B, C, and D (steps S15 to S18). In an image printed by such process, a low-density region such as an image highlight portion or the like is printed using light ink to reduce graininess of ink dots, and a high-density portion is printed using light and dark inks. In this way, the image quality can be improved.

In addition to grayscale expression in each pixel using a plurality of types of multi-density inks, grayscale expression based on dot size modulation by modulating the dot size of ink used in a print process is done. Note that the grayscale expression based on dot size modulation and that using multi-density inks

are normally combined with the multi-drop scheme or pseudo halftoning rather than they are used alone.

As pseudo halftoning, dithering, error diffusion, average density preservation, and the like is known.

- 5 Dithering binarizes each pixel data using threshold values for respective pixels determined by a dither matrix.

- 10 Error diffusion binarizes multi-valued image data of a pixel of interest (converts it into the darkest or lightest level), and distributes and adds the difference (error) between the converted binary level and the value before binarization to surrounding pixels, as described in, e.g., R. FLOYD & L. STEINBERG, "AN ADAPTIVE ALGORITHM FOR SPECIAL GRAY SCALE", SID 75
- 15 DIGEST, pp. 36 - 37.

- 20 Average density preservation obtains a threshold value on the basis of the already binarized binary data around the pixel of interest or values containing the binarization result of the pixel of interest to black or white, and binarizes image data of the pixel of interest using that threshold value, as described in, e.g., Japanese Patent Laid-Open No. 2-210962.

- 25 Furthermore, in addition to these methods, for example, when a transparent image of a medical X-ray film or the like is to be output, the resolution of vision with respect to density increases since it is a transparent image. As a result, even when the

multi-density inks are used, the density differences for respective pixels are recognized, and an image may look coarse. In such case, the number of gray levels per pixel must be increased, and that requirement can
5 be met by increasing the number of multi-density inks.

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In the aforementioned ink-jet printing method, a multi-pass printing method is prevalently used. In a multi-pass printing method using multi-density inks (described in, e.g., Japanese Patent Laid-Open
10 No. 7-47698) forms an ink dot by controlling a plurality of ink droplets discharged from a plurality of print elements of a print head to land on substantially a single pixel, and expresses the gray level of that pixel by appropriately combining the
15 number of ink droplets, and dark and light inks.

However, along with advance of the print technology, an input image to be processed has higher definition, and it is required to reproduce finer representation on a print medium. For this reason,
20 both the input and output signals occupy huge capacity on a memory that stores these signals. In consideration of such situation, the conventional image printing method suffers the following problems.

(1) Ink discharged from a print head may deviate
25 from a predetermined landing position due to nonuniformity of the shape of each ink ejection port of a print head and the surface state of a discharge

surface. This phenomenon is normally called "kink".
Especially, when a given gray level is printed over a
predetermined area or more, and such image is formed to
contain at least ink dots discharged from an identical
5 print element, deviation of the landing position due to
"kink" is recognized as so-called "stripes" having
periodicity, thus deteriorating image quality.

In order to eliminate the influences of "kink",
the aforementioned multi-pass printing method is used.
10 For example, the periodicity of "kink" may be changed
or distributed using a higher-order multi-pass printing
method. However, printing by the higher-order
multi-pass printing method requires a longer print time.
Hence, "stripes" cannot be effectively reduced by a
15 fewer number of passes.

(2) When a given print element does not eject
any ink droplet over a predetermined area or more, an
ink droplet the print element discharges first in that
scan may form an ink dot different from that formed
20 when the print element continuously discharges ink, due
to a change in state of the ink ejection port of that
print element. In this manner, a pixel having a gray
level locally different from that to be printed may be
generated in an image. This phenomenon tends to appear
25 especially in low-density ink, and readily occurs in
the multi-density ink printing method in this sense.

(3) The print head of an ink-jet printing apparatus cannot be permanently used, and may influence the print quality if it damages or stains. For this reason, the print head is exchanged. In this case, it is preferable to obtain equivalent printouts by print heads before and after the exchange. That is, print heads having different characteristics before and after the exchange may change image quality.

(4) When an input image is high-definition, high-resolution information, a gray level that a unit pixel can reproduce is limited. For this reason, upon printing that high-resolution image while its information size remains the same, pseudo halftoning is done. This process is time-consuming.

(5) The print speed can be improved by decimating pixels of an input image, but then the image quality drops.

SUMMARY OF THE INVENTION

The present invention has been made in consideration of the aforementioned problems, and has as its object to provide an ink-jet printing apparatus and method, which can print a high-definition input image having huge image information at high speed without deteriorating its image quality, and a computer readable memory.

5 According to the present invention, the foregoing object is attained by providing, an ink-jet printing apparatus for printing a visible image on a print medium by discharging ink from a plurality of ink ejection print elements, comprising means for storing a first table indicating a correspondence between a plurality of inks and gray scale values of print pixels, means for storing a second table indicating combinations of density distribution patterns of print pixels and the ink ejection print elements in correspondence with the gray scale values, designation means for designating a region consisting of a predetermined number of neighboring pixels from pixels that forms an input image, selection means for selecting the pixel density distribution pattern for the designated region, and control means for controlling ink ejection/non-ejection of ink from the plurality of ink ejection print elements by looking up the first and second tables in accordance with the pixel density distribution pattern and a gray scale value thereof.

25 According to the present invention, the foregoing object is attained by providing, an ink-jet printing method for printing a visible image on a print medium by discharging ink from a plurality of ink ejection print elements, comprising the designation step of designating a region consisting of a predetermined

number of neighboring pixels from pixels that forms an input image, the selection step of selecting a pixel density distribution pattern for the designated region, and the control step of controlling ink

5 ejection/non-ejection of ink from the plurality of ink ejection print elements by looking up a first table indicating a correspondence between a plurality of inks and gray scale values of print pixels and a second table indicating combinations of density distribution
10 patterns of print pixels and the ink ejection print elements in correspondence with the gray scale values in accordance with the pixel density distribution pattern and a gray scale value thereof.

Other features and advantages of the present
15 invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the arrangement of an ink-jet printing apparatus according to an embodiment of the present invention;

25 Fig. 2 is a view showing the arrangement of a printer unit of the ink-jet printing apparatus according to the embodiment of the present invention;

Fig. 3 shows a print element combination table according to the embodiment of the present invention;

Fig. 4 shows the print element combination table according to the embodiment of the present invention;

5 Fig. 5 shows the print element combination table according to the embodiment of the present invention;

Fig. 6 is a flow chart showing the flow of an image process in the ink-jet printing apparatus according to the embodiment of the present invention;

10 Fig. 7 is a view for explaining a multi (4)-pass printing method;

Fig. 8 shows ink-jet print element arrays in each of which 16 print elements line up in the main scan direction;

15 Fig. 9 show ink-jet print element arrays including print element arrays capable of printing multi-size dots of light ink, and those capable of printing multi-size dots of dark ink;

Fig. 10 shows ink-jet print element arrays that 20 can print using four different multi-density inks;

Fig. 11 shows an example of combination patterns of print elements;

Fig. 12 shows an example of a print ink combination table;

25 Fig. 13 shows the contents of a multi-density ink combination table using two different multi-density inks (dark and light inks); and

Fig. 14 is a flow chart showing the flow of an image process using an ink distribution table shown in Fig. 13.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

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A preferred embodiment of the present invention will be described in detail hereinafter with reference to the accompanying drawings. Note that a "density" hereinafter means an optical density of ink land on a printing medium. Further, a "multi-density" ink means that there are different optical densities of inks.

<Relationship Between Image Print Process and Multi-density Inks>

In general, an image has a gray level for each pixel, and a desired image is printed and reproduced using a unit pixel (a minimum unit that forms a print pixel and differs depending on image printing apparatuses) which prints that gray level.

For example, an image printing apparatus which can control 16 ink droplets to land on a unit pixel can print 16 + 1 (blank paper) gray levels on the unit pixel. At this time, if inks having two different densities can be prepared, the number of gray levels that can be reproduced becomes 32 or more although it depends on the density ratio of inks.

On the other hand, if two different ink droplet volumes can be prepared, the number of gray levels can

be increased as in the ink density, and if different ink densities and ink droplet volumes are combined, the number of gray levels that can be reproduced on one unit pixel can exceed 256.

- 5 For example, when n different multi-density inks are used, if one pixel is formed by one dot alone, the number of combinations of the numbers of dots formed by respective multi-density inks (to be referred to as "multi-density combinations" hereinafter) is ${}_nC_1 = n$
- 10 upon selecting only one out of n different multi-density inks. On the other hand, if one pixel is formed by two dots, ${}_nC_2 = n(n-1)/2$ combinations upon selecting two out of n different multi-density inks and forming one dot by each ink, and ${}_nC_1 = n$ combinations
- 15 upon selecting one out of n different multi-density inks and forming two dots by that ink are available.

More specifically, the number of multi-density combinations increases with increasing number of dots that can be formed per pixel, and with increasing

20 number of types of multi-density inks used. Also, many multi-density combinations produce substantially the same gray levels depending on the density ratio of multi-density inks used. Furthermore, in addition to the number of types of multi-density inks, when several

25 different multi-size dots are formed by ink droplets having different volumes, the number of combinations further increases.

The number of ink dots that can form a unit pixel depends on the characteristics of a print medium, the ejection volume of ink, and the like, and is limited in terms of the print speed and print system. In general,
5 that number of ink dots assumes a value of around 30 to 600 ng/300-dpi pixel in the weight or volume of an ink droplet.

When the image to be printed has a high resolution or a large number of gray levels, the input
10 image size becomes large, and both the host that processes an image to be printed (e.g., transfers the image to the printing apparatus) and the printing apparatus require much time. Hence, in the present invention, for example, four (2×2) pixels of an input
15 image are considered as one pixel. As a result, the information size of the input image is reduced to $1/4$, and the time required to print can be consequently shortened. Note that an input image is reduced in resolution since 2×2 pixels of the input image are
20 considered as one pixel, but a solution to this problem will be explained later.

On the other hand, when a print element array prepared by integrating and lining up a plurality of print elements is used, print elements that can print
25 an identical pixel on a print medium upon executing, for example, 4-pass print processes using an ink-jet print element array in which 16 print elements are set

in the main scan direction, as shown in Fig. 8, can be selected from a total of four print elements a-1-1, a-2-1, a-3-1, and a-4-1 of the print element array shown in Fig. 8.

5 As described above, in the print method for forming a plurality of ink dots in a single pixel, if the print element array shown in Fig. 8 is taken as an example, and two ink dots are printed in a single pixel, $4C_2 = 6$ different combinations are available.

10 Furthermore, when a plurality of multi-density inks are used, and when a print element array that discharges a plurality of ink droplets with an identical density is used, and print elements eject ink with different ink droplet volumes to form multi-size
15 dots, the aforementioned number of combinations increases. For example, when a combination of multi-density inks, in which the optical density of dark ink on a print medium exhibits a density substantially twice that of light ink, and a
20 combination of dot sizes in which the large dot volume is nearly twice the small dot volume are used, the following combinations are available.

Fig. 9 shows ink-jet print element arrays including print element arrays (6-a, 6-b) capable of
25 printing multi-size dots of light ink (ink A), and print element arrays capable of printing multi-size dots of dark ink (ink B). When the maximum number of

ink droplets that can practically land on a single pixel is limited to two for each of multi-size dots, many combinations of gray levels can be expressed.

In consideration of combinations of print
5 elements used to print a given pixel, for example, when
a print element array passes over a print pixel four
times upon reproducing a given gray scale value, many
combinations of passes and ink dots to be printed are
available. In the present invention, combinations of
10 nozzles to be driven are stored as tables (print
element combination tables: second tables), and a
combination is selected in accordance with each input
image.

By systematically managing the number of dots
15 printed by multi-density inks and the print elements
used to print by the many print element combination
tables, a combination of a series of print elements to
be used actually is selected.

Since the number of selectable combinations
20 becomes huge with increasing number of types of ink
densities, number of types of ink droplet volumes, and
number of passes of the multi-pass print control, a
limited number of print element combination tables are
preferably stored in practice, thus contributing to a
25 high-speed image print process.

Fig. 11 shows an example of combination patterns
of print elements stored in this way. As can be seen

from patterns a to o in Fig. 11, even when an identical gray scale value is printed within 2×2 pixels, the printed gray scale value varies depending on unit pixels. Such variation is called a density distribution in a print pixel (density distribution pattern of a print pixel).

The density distribution in a print pixel is stored in the aforementioned print ink combination table (first table) as classes (density gradient information) a to o shown in, e.g., Fig. 11. Fig. 12 shows an example of a print ink combination table (first table) generated in this way, which stores five patterns (patterns 1 to 5) for the sake of simplicity. Numerical values shown in Fig. 12 indicate the numbers of ink droplets to be printed in a unit pixel upon forming respective patterns when a maximum of 16 ink droplets are printed in 2×2 print pixels.

When a pattern to be used is selected from the print ink combination table on the basis of the pixel value of an input image, the gray scale value of a unit pixel of the input image cannot often match that of a unit pixel of a print image depending on the combination table used. However, although the gray scale value varies slightly, image data can be rasterized while reducing the information size of the input image, and an image can be printed without sacrificing the resolution.

Note that a method of selecting a pattern of the print ink combination table on the basis of the gray scale value of a pixel of an input image is not particularly limited. For example, the following method may be used.

When the gray scale value and average of the unit pixel of interest (e.g., the upper left pixel of 2×2 pixels) are separated a predetermined value or more from the total and average of the 2×2 pixels of an input image, a pattern according to the feature of the four ($= 2 \times 2$) pixels is selected. However, when the gray level and average of the unit pixel of interest are not separated by the predetermined value or more, it is estimated that other three pixels are not separated either.

The gray scale value and print element combination used are determined for each pixel from a series of print element combination patterns selected in this way on the basis of an input image. If there are a plurality of combinations of gray scale values, patterns, and print element combinations, which exhibit substantially the same density, are present, for example, if three different combinations A, B, and C produce substantially the same gray scale value, three different print element combinations are sequentially used for respectively pixels like ABCABCABC,... upon expressing that gray scale value.

Alternatively, it is preferable to randomly use these three different print element combinations like ABCCBABBCAA,.... Note that this random selection method is not particularly limited.

5 <Description of Ink-jet Printing Method>

Any of known ink-jet printing methods that print by discharging small ink droplets via nozzles by exploiting various drive principles can be applied to an image printing apparatus (ink-jet printing
10 apparatus) according to this embodiment. For example, an ink-jet method that discharges ink from a nozzle by an abrupt change in volume of ink caused by applying heat energy to the ink (Japanese Patent Laid-Open No. 54-59936) can be applied.

15 An ink-jet printing apparatus that can suitably adopt that ink-jet printing method will be explained below. Fig. 2 shows the arrangement of a printer unit of the ink-jet printing apparatus according to this embodiment.

20 A plurality of ink-jet units 21-1 to 21-4 are mounted on a carriage 20 of the ink-jet printing apparatus shown in Fig. 2. These ink-jet units have print element arrays for discharging ink, which are set at a predetermined spacing. Ink cartridges 22-1, 22-2,
25 22-3, and 22-4 supply inks to the corresponding print element arrays of the ink-jet units 21-1 to 21-4. Of these ink cartridges, the ink cartridges 22-1 and 22-3

supply light ink, and the ink cartridges 22-2 and 22-4 supply dark ink. Note that the respective densities will be explained later.

Control signals and the like are sent to the
5 ink-jet units 21-1 to 21-4 via a flexible cable 23. A print sheet 24 such as a paper sheet, plastic thin plate, or the like is clamped by a discharge roller 25 via a feed roller (not shown), and is fed in the direction of an arrow in Fig. 2 upon driving a feed
10 motor 26.

The carriage 20 is guided and supported by a guide shaft 27 and linear encoder 28. The carriage 20 reciprocally moves along the guide shaft 27 via a drive belt 29 by driving a carriage motor 30. Heating
15 elements for producing heat energy for ink ejection (electrothermal energy converters) are provided inside (ink channels of) the ink ejection ports of the ink-jet units 21-1 to 21-4.

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The aforementioned print elements are driven
20 based on a predetermined print signal in accordance with the read timing of the linear encoder 28, and form an image by making ink droplets fly and become attach onto the print sheet 24.

A recovery unit 32 having a cap unit 31 is set at
25 the home position of the carriage 20, which is set outside the print region. While the print process halts, the carriage 20 moves to the home position, and

caps 31-1 to 31-4 of the cap unit 31 cap the ink
ejection port surfaces of the corresponding ink-jet
units 21, thus preventing ink from drying due to
evaporation of an ink solvent or clogging due to
5 attachment of foreign matter such as dust or the like.

The capping function of the cap unit 31 is used
in idle ejection for discharging ink toward the cap
unit separated from the ink ejection ports so as to
eliminate ejection errors and clogging of the ink
10 ejection ports which print less frequently, and in
ejection recovery of ejection ports that have caused
ejection errors by drawing ink by suction therefrom by
activating a pump (not shown) while being capped.

An ink pan 33 receives ink preliminarily
15 discharged by the ink-jet units 21-1 to 21-4 when they
pass above the ink pan 33 immediately before an actual
print process. When a blade or cleaning member (not
shown) is arranged at a neighboring position of the cap
unit, the ink ejection port formation surfaces of the
20 ink-jet units 21-1 to 21-4 can be cleaned.

In this ink-jet printing apparatus, two print
heads having print element arrays for each of two,
light and dark inks are juxtaposed laterally on the
ink-jet units 21-1 to 21-4. However, the present
25 invention is not limited to such specific arrangement,
and the print heads may be divided not laterally but
vertically. Furthermore, in place of arranging the

print element arrays laterally, one print element array may be vertically divided into four subarrays.

A color print process can be attained by mounting print heads that respectively store black, cyan,
5 magenta, and yellow inks on the carriage. Furthermore, a plurality of multi-density inks and multi-size dots may be used for each color.

<Arrangement of Ink-jet Printing Apparatus>

The arrangement and operation of the ink-jet
10 printing apparatus according to this embodiment will be described below. A case will be explained below wherein a 600-dpi, high-definition, 256-level monochrome medical X-ray transparent image is formed using black ink under the condition that a maximum of
15 four ink droplets can land per unit pixel, one print pixel is formed by four ($= 2 \times 2$) unit pixels, and a maximum of eight ink droplets can land within the print pixel.

Fig. 1 is a block diagram showing the arrangement
20 of the ink-jet printing apparatus according to this embodiment.

Referring to Fig. 1, reference numeral 1 denotes an image input unit; 2, a console; 3, a central processing unit (CPU) for making various processes; and
25 4, a storage medium for storing various data. The storage medium 4 stores print element combination information 4a in the form of a table, and various

control programs 4b. Reference numeral 5 denotes a
RAM; 6, an image processor; 7, a printer controller for
making image output control; and 8, a bus (bus line)
for interconnecting the respective building components
5 and transferring various data.

The image input unit 1 comprises, e.g., a scanner,
digital camera, or the like. The console 2 comprises
various keys used to set various parameters, and to
instruct the start of a print process. The CPU 3
10 controls the overall ink-jet printing apparatus of this
embodiment in accordance with various programs in the
storage medium 4.

The storage medium 4 stores programs for making
the ink-jet printing apparatus operate in accordance
15 with a control program, an error processing program,
and the like. All the operations of this ink-jet
printing apparatus are implemented by those programs.
As the storage medium 4 that stores the programs, for
example, a ROM, FD, CD-ROM, HD, memory card,
20 magnetooptical disk, or the like can be used.

The RAM 5 is used as a work area for various
programs in the storage medium 4, a temporary save area
in an error process, and a work area in an image
process. Also, after various tables in the storage
25 medium 4 are copied to the RAM 5, the contents of these
tables may be changed, and a predetermined image

process may be executed by looking up the changed tables.

The image processor 6 generates a discharge pattern that implements multi-level expression by the ink-jet method on the basis of an input image. The printer controller 7 forms a dot image on the basis of the ejection pattern generated by the image processor 6 upon printing an image. The bus line 8 interconnects the building components, and transfers an address signal, data, control signal, and the like in the ink-jet printing apparatus.

The aforementioned print element combination information 4a stores data that pertains to inks used. The ink used in this embodiment is one type. However, as will be described later, light and dark inks may be prepared for the purpose of printing ink dots of the same hue having different densities, and are effective to reproduce many gray scale values.

Note that the ink is comprised of a color agent (dye and/or pigment) and a solvent, which contains various additives such as a surfactant, humectant, and the like. These additives control ejection characteristics from the print heads and absorption characteristics on a print sheet.

When one unit pixel is formed by a maximum of four ink dots using such ink, many print ink combination tables that can express a print pixel

consisting of 4 ($= 2 \times 2$) unit pixels are available.
In this embodiment, of these tables, a total of 144 + 1
print ink combination tables (a total of five different
patterns including four patterns having high density
offsets respectively at the upper left, upper right,
lower left, and lower right pixel positions in a 2×2
pattern, and an offset-less pattern for respective gray
scale values, and (8+1) values for respective print
pixels) are used.

10 Figs. 3 to 5 show the print ink combination table
(second table) according to this embodiment.

Of numerical values in Figs. 3 to 5, "1"
indicates ejection of an ink droplet; "0", non-ejection
of an ink droplet. For the sake of simplicity, as
15 information associated with the positions in a 2×2
matrix, LU, RU, LL, and RL respectively indicate upper
left, upper right, lower left, and lower right pixels,
and a group of ink combination tables in each of which
a given unit pixel has a higher density offset than
20 other unit pixel is expressed as density patterns.

The density level is not perfectly proportional
to the total of the number of inks discharged per pixel,
and the pigment content of ink, but no practical
problem is posed for a low-density portion of a
25 reflecting print medium or transparent print medium if
so assumed.

Fig. 6 is a flow chart showing the flow of an image process in the ink-jet printing apparatus according to this embodiment.

The image process unique to this embodiment will
5 be explained below with reference to Figs. 3 to 6.

When the print element combination table shown in Figs. 3 to 5 is used, the number of gray levels of a 256-level input image input in step S101 in Fig. 6 must be converted to a (2+1) value (/600 dpi). The image
10 processor 6 in Fig. 1 executes a (2+1)-valued error diffusion process (steps S102 and S103). Note that multi-valued error diffusion is used in this process, but the present invention is not limited to such specific method, and arbitrary halftoning methods such
15 as average density preservation, dither matrix method, and the like may be used.

The multi-valued error diffusion is different from normal error diffusion in that a plurality of threshold values (two in this embodiment) for
20 binarization are used. These threshold values may be normally midpoints of gray levels.

The image processor 6 distributes the data that has undergone the multi-valued process as ejection/non-ejection drive signals to respective print
25 elements in accordance with the print ink combinations shown in Figs. 3 to 5 with reference to the print element combination information 4a in the storage

medium 4. Since the source image data is at 600 dpi, multi-valued data has (2+1) values at 600 dpi, i.e., three values "0", "1", and "2" (step S103 in Fig. 6).

It is checked in step S104 if the average value
5 of the print pixel of interest has a predetermined difference (k: e.g., $k = 1$) from the gray level of the upper left dot. A case will be exemplified below wherein the upper left unit pixel ($i1, j1$) of the 2×2 print pixel (expressed by ($I1, J1$)) of interest has a
10 gray scale value = 2, the upper right unit pixel ($i1+1, j1$) has a gray scale value = 1, the lower left unit pixel ($i1, j1+1$) has a gray scale value = 1, and the lower right unit pixel ($i1+1, j1+1$) has a gray scale value = 0. In this case, since the density gradient
15 information indicates that the upper left density is high, a density pattern "LU" corresponding to a grayscale pattern "a" shown in Fig. 11 is selected (steps S105 and S110).

Since the gray level of the 2×2 print pixel
20 itself is $4/8$, it is determined that data are distributed on the basis of pattern information having density gradient information "LU" (i.e., combinations Nos. 45 to 48) of the print element combination information of density 4 (gray level 4) shown in Fig. 4.
25 In practice, one of these four combinations is selected in turn or randomly (steps S115 and S116).

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With the aforementioned process, the process for one print pixel of interest is complete. The same process is repeated for the next 2×2 print pixel (I2, J2).

5 For example, when the upper left unit pixel (i2, j2) of that print pixel has a gray level = 2, the upper right unit pixel (i2+1, j2) has a gray scale value = 2, the lower left unit pixel (i2, j2+1) has a gray scale value = 2, and the lower right unit pixel (i2+1, j2+1) has a gray scale value = 1, its density gradient information corresponds to grayscale pattern "1" shown in Fig. 11. Since it is difficult to determine that this pattern belongs to any of LU, RU, LL, and RL, "AVE" is selected in this case for the sake of
10 simplicity (step S114).
15

Since the gray level of this print pixel is 7/8, it is determined that data are distributed on the basis of pattern information having density gradient information "AVE" (i.e., combinations Nos. 21 to 24) of
20 the print element combination information of density 7 (gray level 7) shown in Fig. 5 (steps S115 and S116).

By repeating the aforementioned process for all print pixels on the basis of the density data of that image, binary drive signals indicating
25 ejection/non-ejection for respective pixels of each print element array are formed (steps S120 to S123).

Fig. 7 shows a multi (4)-pass printing method, in which the print processes of respective passes are done by a print head 6-a having a print element array for discharging ink A, a print head 6-b having a print
5 element array for discharging ink A, a print head 6-c having a print element array for discharging ink B, and a print head 6-d having a print element array for discharging ink B.

In this embodiment, all pixels are sequentially
10 processed, as described above, and are printed by the 4-pass printing processes by the ink-jet printing apparatus (Fig. 2) having the print element arrays shown in Figs. 8, 9, and 10.

As described above, according to this embodiment,
15 since a region specified by combining neighboring unit pixels of an input image defines a print pixel, and predetermined gray scale value patterns are selected for respective print pixels in accordance with the input image, the information size of the image data can
20 be reduced to around 1/4 without decreasing the resolution of the input image, and a high-speed image print process and a load reduction on the controller (CPU) can be attained.

In the ink-jet print method for printing two ink
25 droplets on at least a single unit pixel, printing ink droplets by at least two multi-size dots, or printing at least two multi-density ink droplets for the same

hue, and in the image print method for printing by
discharging one or a plurality of ink droplets as
needed for some unit pixels that form a print pixel as
a building unit of an image to be printed, control data
5 of patterned ejection/non-ejection drive signals are
effectively processed without any complicated image
processes.

Furthermore, since a plurality of pieces of print
element combination information are prepared for a
10 single gray scale value, and a print process is done
sequentially or randomly using different contents of
print element combination information, identical print
elements can be prevented from simultaneously forming
ink dots over a given area or more, and a change in
15 characteristics can be suppressed even when the print
heads are exchanged, thus positively and effectively
coping with the variations of the characteristics of
the print elements.

An image which has good halftone characteristics
20 and is free from deterioration due to "kink" or the
like can be obtained by a high-speed, simple process
using a simple signal algorithm, and a high-quality
halftone image can be obtained even when a print
process is done using low-resolution data as
25 information.

[Modification]

The present invention is not limited to the
aforementioned embodiment, and various modifications
may be made. For example, two multi-density inks are
prepared, and a print process is done using single dot
5 size (see Fig. 9). The following two different inks
are used, and are represented by A and B in ascending
order of pigment density in ink. Table 1 shows the
pigment density ratios of these inks.

[Table 1]

	A	B
Transmission Density	0.2	0.8
Dye Density Ratio	1	4

10 Also, print elements which can print the
aforementioned two different multi-density inks and
also two different multi-size ink droplets are prepared
(see Fig. 9). For example, in Table 2 below, A, B, C,
and D respectively indicate approximate values of
15 transmission densities when a solid print process at a
print density ratio = 100% is done respectively using
light ink and small dots, light ink and large dots,
dark ink and small dots, and dark ink and large dots.
In this way, a high-quality halftone image can be
20 obtained.

[Table 2]

	A	B	C	D
Transmission Density	0.1	0.2	0.4	0.8
Pigment Density Ratio	1	2	4	8

Furthermore, four multi-density inks may be prepared. In this case, the same print process as in the above embodiment is done using a single dot size (see Fig. 10). A, B, C, and D respectively represent inks in ascending order of pigment density in the ink. Table 3 below shows the pigment density ratios of the inks. With this method as well, a high-quality halftone image can be obtained.

10 [Table 3]

	A	B	C	D
Transmission Density	0.1	0.2	0.4	0.8
Pigment Density Ratio	1	2	4	8

In the above embodiment, the (8+1) value of a print pixel consisting of a maximum of 2×2 , i.e., four unit pixels may be normalized by 256 values to numerical values 0, 32, 64, 80, ..., 240, 255, and may be compared with the gray level of an input pixel without executing the multi-valued process of input high-definition image data to select the nearest gray scale value.

Note that the present invention may be applied to either a system constituted by a plurality of devices

(e.g., a host computer, an interface device, a reader, a printer, and the like), or an apparatus consisting of a single equipment (e.g., a copying machine, a facsimile apparatus, or the like).

5 The objects of the present invention are also achieved by supplying a storage medium, which records a program code of a software program that can implement the functions of the above-mentioned embodiments to the system or apparatus, and reading out and executing the
10 program code stored in the storage medium by a computer (or a CPU or MPU) of the system or apparatus. In this case, the program code itself read out from the storage medium implements the functions of the above-mentioned embodiments, and the storage medium which stores the
15 program code constitutes the present invention.

 The functions of the above-mentioned embodiments may be implemented not only by executing the readout program code by the computer but also by some or all of actual processing operations executed by an OS
20 (operating system) running on the computer on the basis of an instruction of the program code.

 Furthermore, the functions of the above-mentioned embodiments may be implemented by some or all of actual processing operations executed by a CPU or the like
25 arranged in a function extension card or a function extension unit, which is inserted in or connected to the computer, after the program code read out from the

storage medium is written in a memory of the extension card or unit.

When the present invention is applied to the storage medium, that storage medium stores a program
5 code corresponding to the aforementioned flow chart (e.g., shown in Fig. 6).

As described above, the present invention can provide an ink-jet printing apparatus and method, which
can print a high-definition input image having a huge
10 image information size at high speed without deteriorating image quality, and a computer readable memory.

The present invention is not limited to the above embodiments and various changes and modifications can
15 be made within the spirit and scope of the present invention. Therefore, to apprise the public of the scope of the present invention the following claims are made.